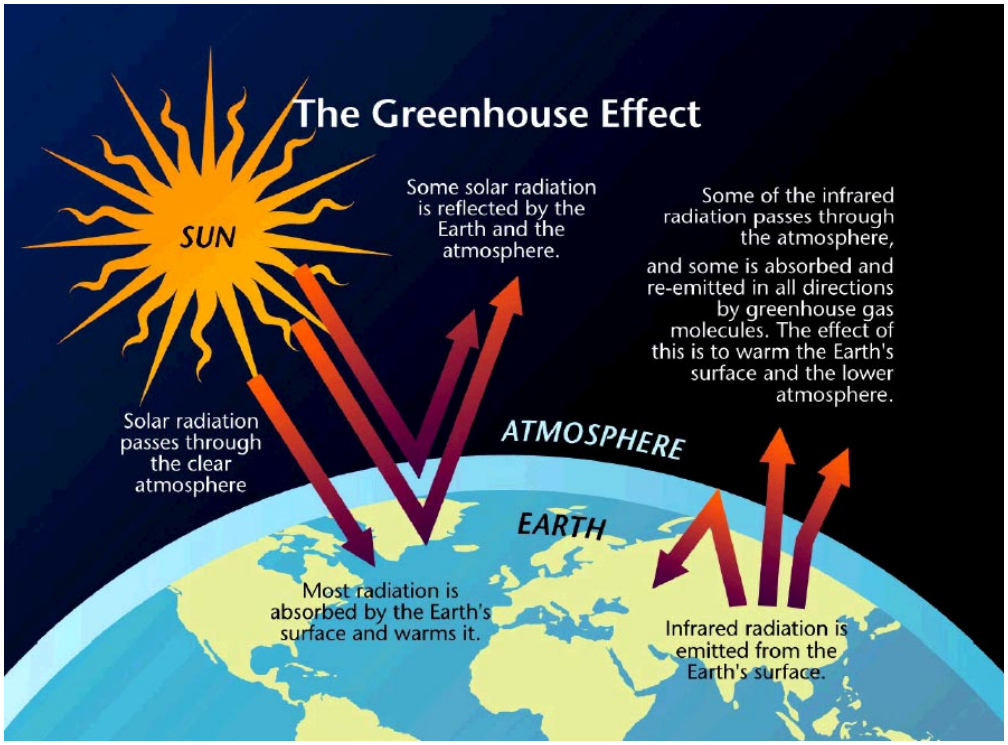
CLIMATE

WHAT WE ARE ***DOING*** TO IT AND WHAT WE ARE DOING TO ***UNDERSTAND*** IT



Stephen E. Schwartz

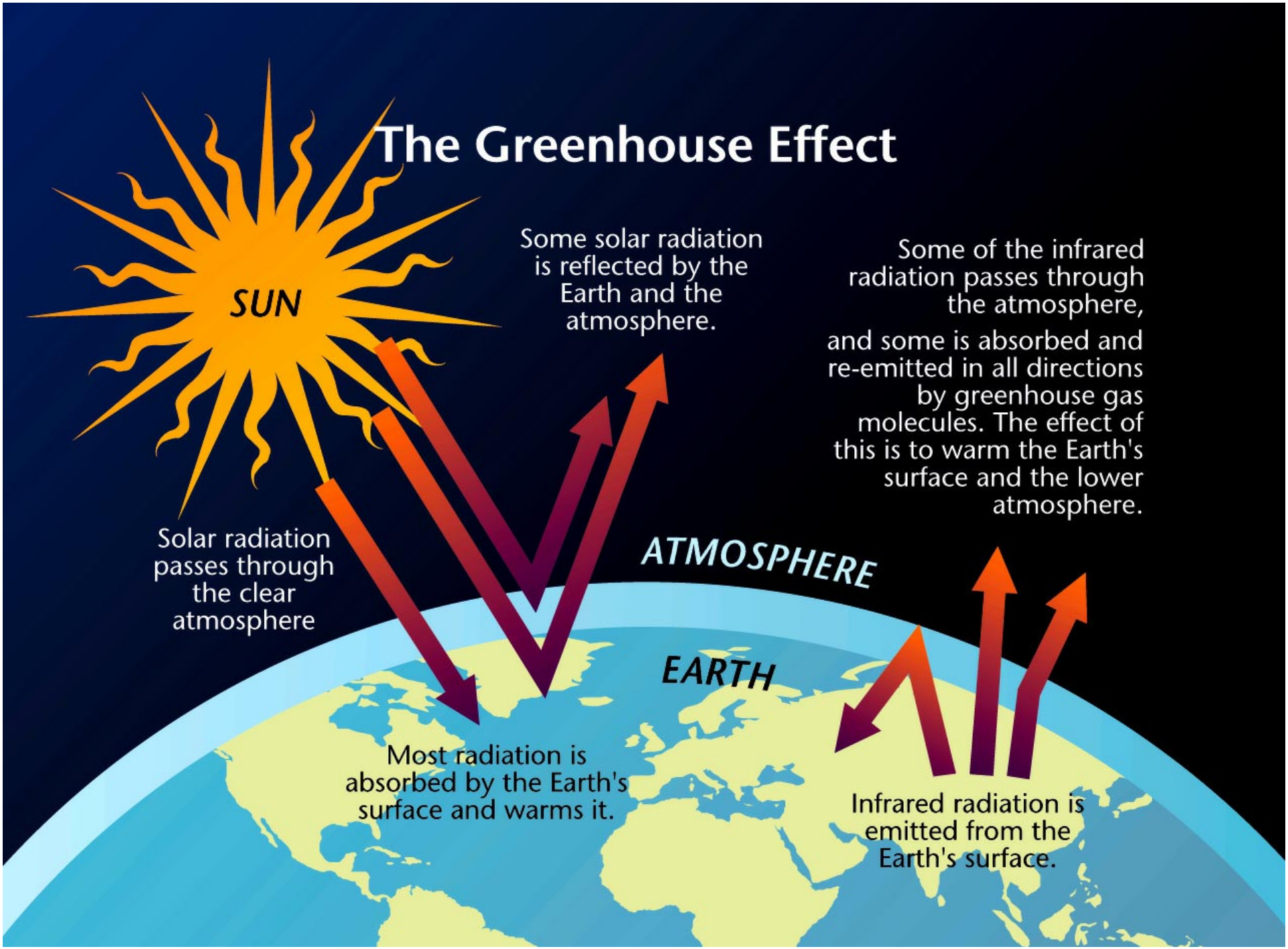
Environmental Sciences Department

BROOKHAVEN NATIONAL LABORATORY

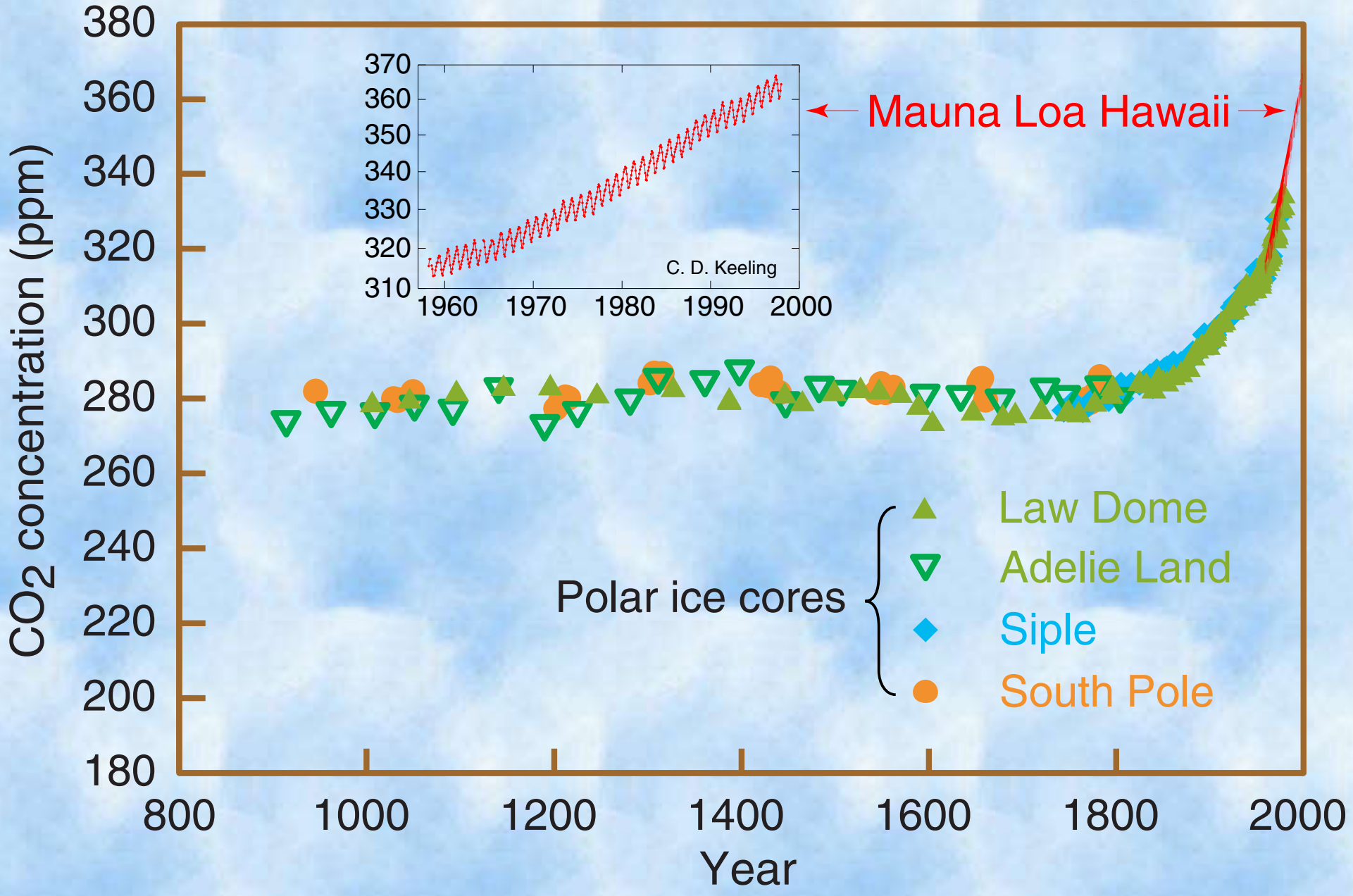
BNL Management Council

April 20, 2004

http://www.ecd.bnl.gov/steve/schwartz.html

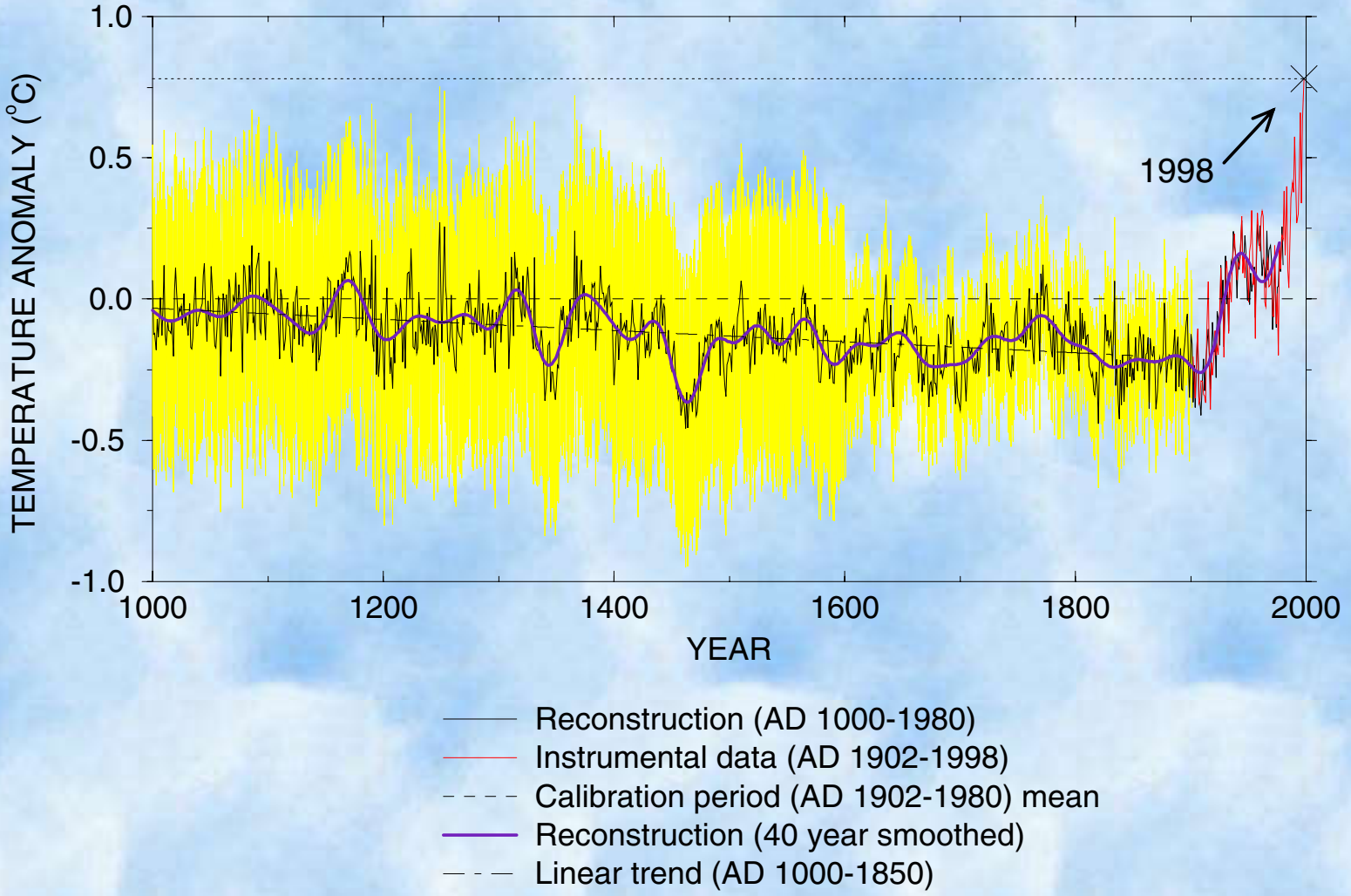

The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration over the last thousand years

THE TEMPERATURE'S RISING



Northern Hemisphere temperature trend (1000-1998), from tree-ring, coral, and ice-core proxy records As calibrated by instrumental measurements.

Mann et al., Geophysical Research Letters, 1999

WHERE IS ALL THIS CO_2 COMING FROM?

WHO IS RESPONSIBLE?

HOW MUCH CARBON IS IN A GALLON OF GASOLINE?

1 lb?

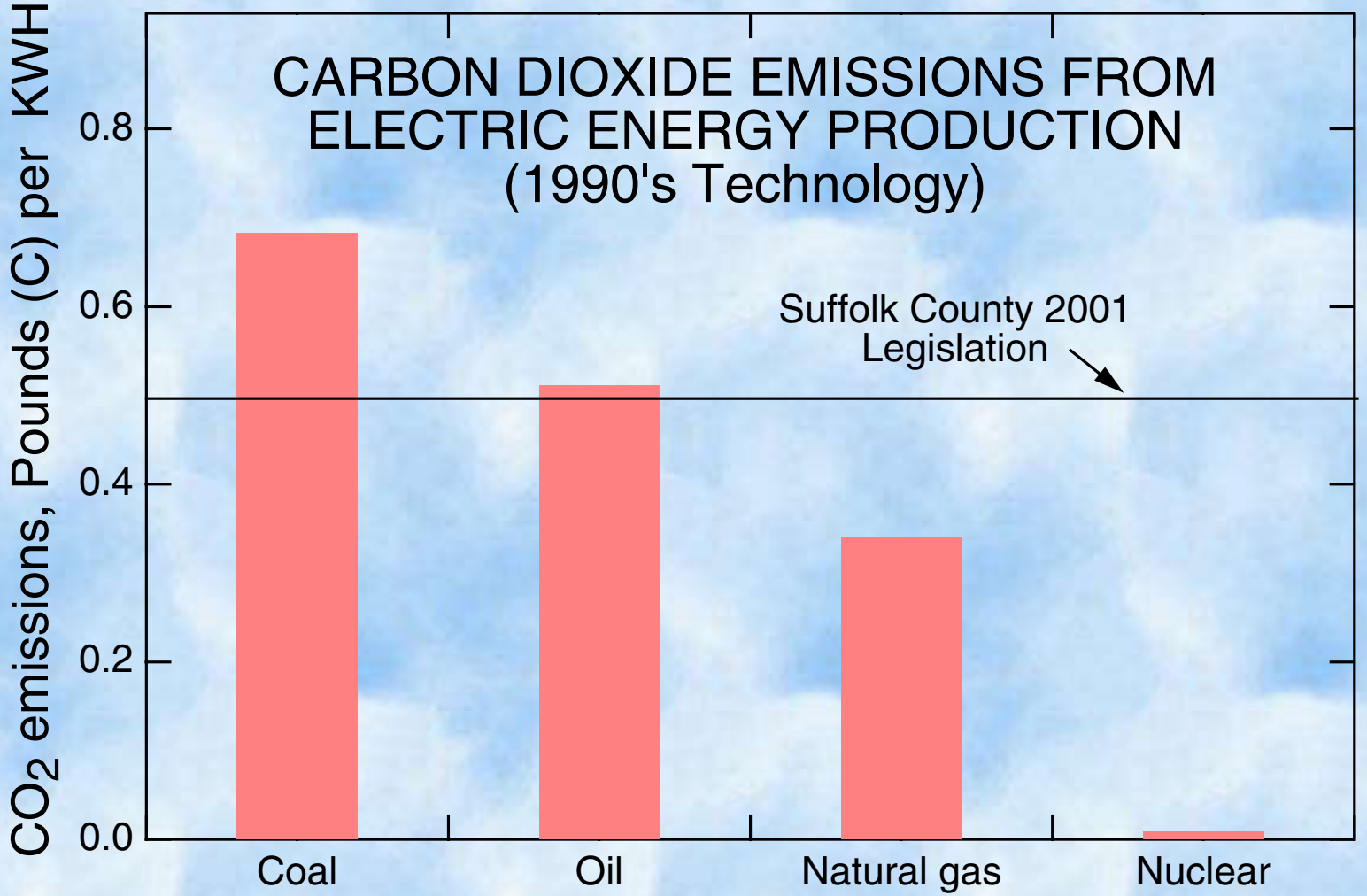
2 lbs?

3 lbs!?

5 lbs!?!

All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

YOUR FAMILY'S CONTRIBUTION TO THE GREENHOUSE EFFECT



A typical household using 1000 kilowatt hours of electricity per month is responsible for emission of 3 tons of carbon a year in the form of carbon dioxide.

How much does your household contribute?

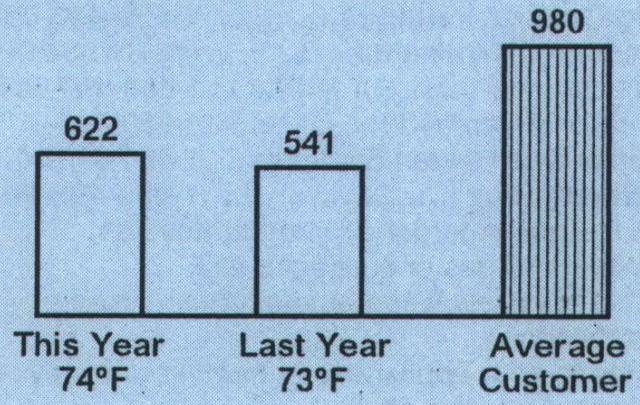
YOUR CONTRIBUTION TO THE GREENHOUSE EFFECT

ELECTRIC SUPPLY AND DELIVERY FROM LIPA

Meter Readings Meter # 15790134

	Jul 24	93155 Actual
	Jun 26	92533 Actual
Use	28 **Days**	622 **KWH**

Comparisons KWH



Cost Rate 880 - Water and Home Heating

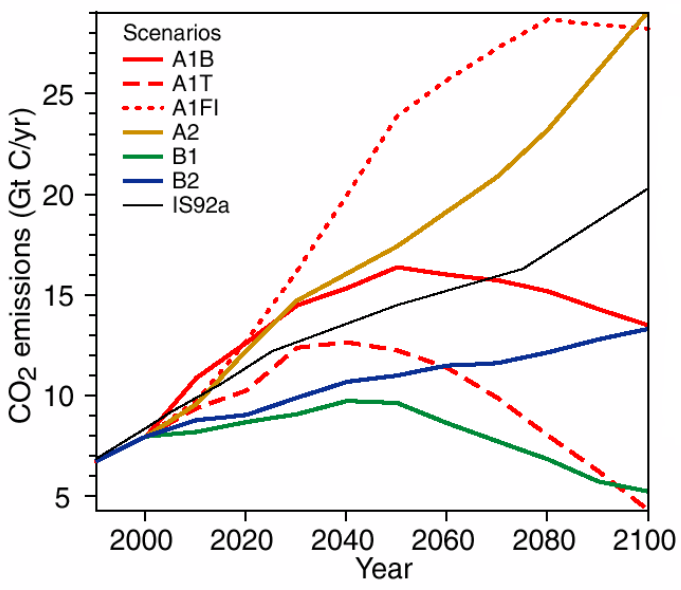
Basic Service: 28 Days @ 17.90¢	$5.01
Use: 233 KWH @ 12.49¢	29.10
140 KWH @ 13.67¢	19.14
249 KWH @ 9.78¢	24.35
Excess Fuel Price Surcharge	4.28
PILOTs and Credits	1.40
Shoreham Credit	-.59
Sales Tax: @ 1%	.83
Total	$83.52

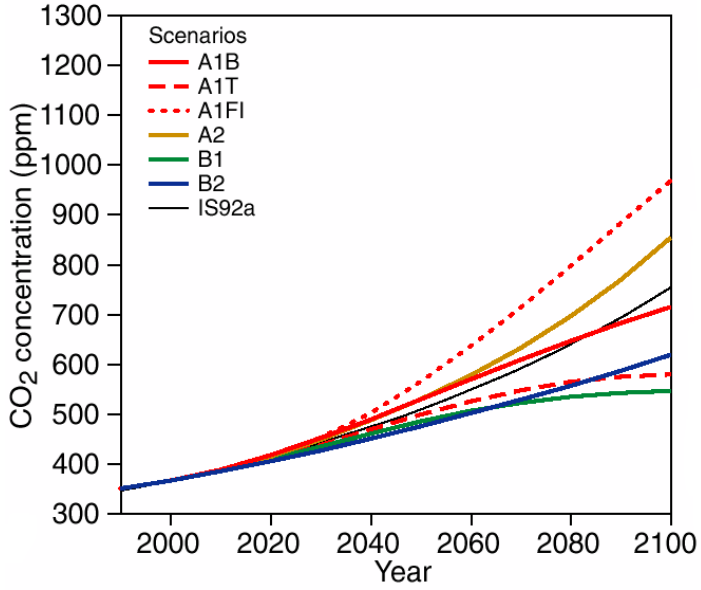
LIPA
Long Island Power Authority

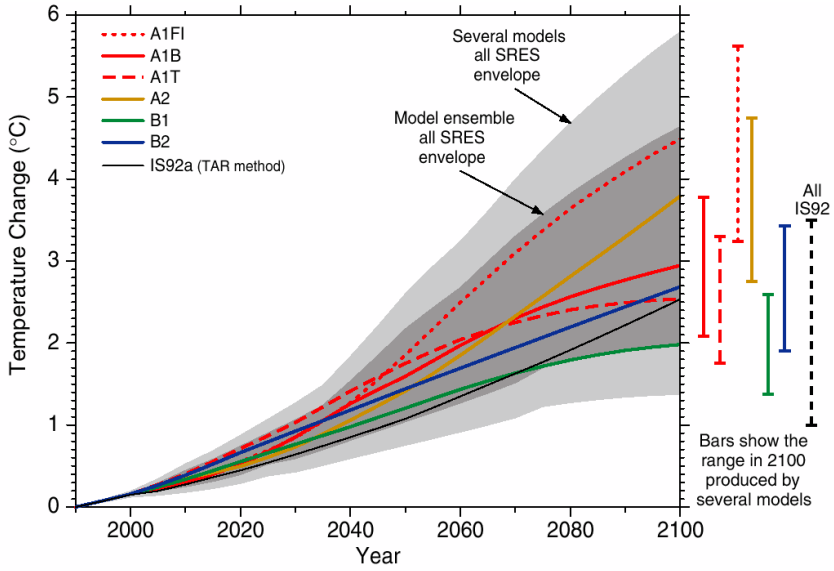
Jul 25, 2001	927 20 1805 3 5	1-800-490-0025	See Back Of Bill
Date	Account Number	Any Questions?	Service Problems

At half a pound of carbon per KWH, the average household is responsible for emission of 500 pounds of carbon a month.

FUTURE CLIMATE IS HIGHLY UNCERTAIN







(*IPCC, 2001*)

Contributors to uncertainty include ***emissions***, ***concentrations***, and the Earth's ***climate sensitivity***.

CLIMATE RESPONSE

The ***change*** in global and annual mean temperature, ΔT, K, resulting from a given radiative forcing.

Working hypothesis:

The change in global mean temperature depends on the magnitude of the forcing, not its nature or its spatial distribution.

$$\Delta T = \lambda F$$

CLIMATE SENSITIVITY

The ***change*** in global and annual mean temperature per unit forcing, λ, K/(W m^{-2}).

TOP-LEVEL QUESTION IN CLIMATE CHANGE SCIENCE

- ***How much will the global mean temperature change?***

$$\Delta T = \lambda F$$

where F is the ***forcing*** and λ is the ***climate sensitivity***.

- A ***forcing*** is a change in a radiative flux component, W m^{-2}.
- Forcings are thought to be ***additive*** and ***fungible***.

- ***What is Earth's climate sensitivity?***
  - ***National Academy Report (Charney, 1979):*** F = 4 W m^{-2}

"We estimate the most probable global warming for a doubling of CO_2 to be ***near 3 degrees C***, with a probable error of ***plus or minus 1.5 degrees***.

- ***Intergovernmental Panel on Climate Change (IPCC, 2001):***

"Climate sensitivity [to CO_2 doubling] is likely to be in the range ***1.5 to 4.5˚C***.

This uncertainty is not very useful for policy planning.

HOW CAN CLIMATE SENSITIVITY BE DETERMINED?

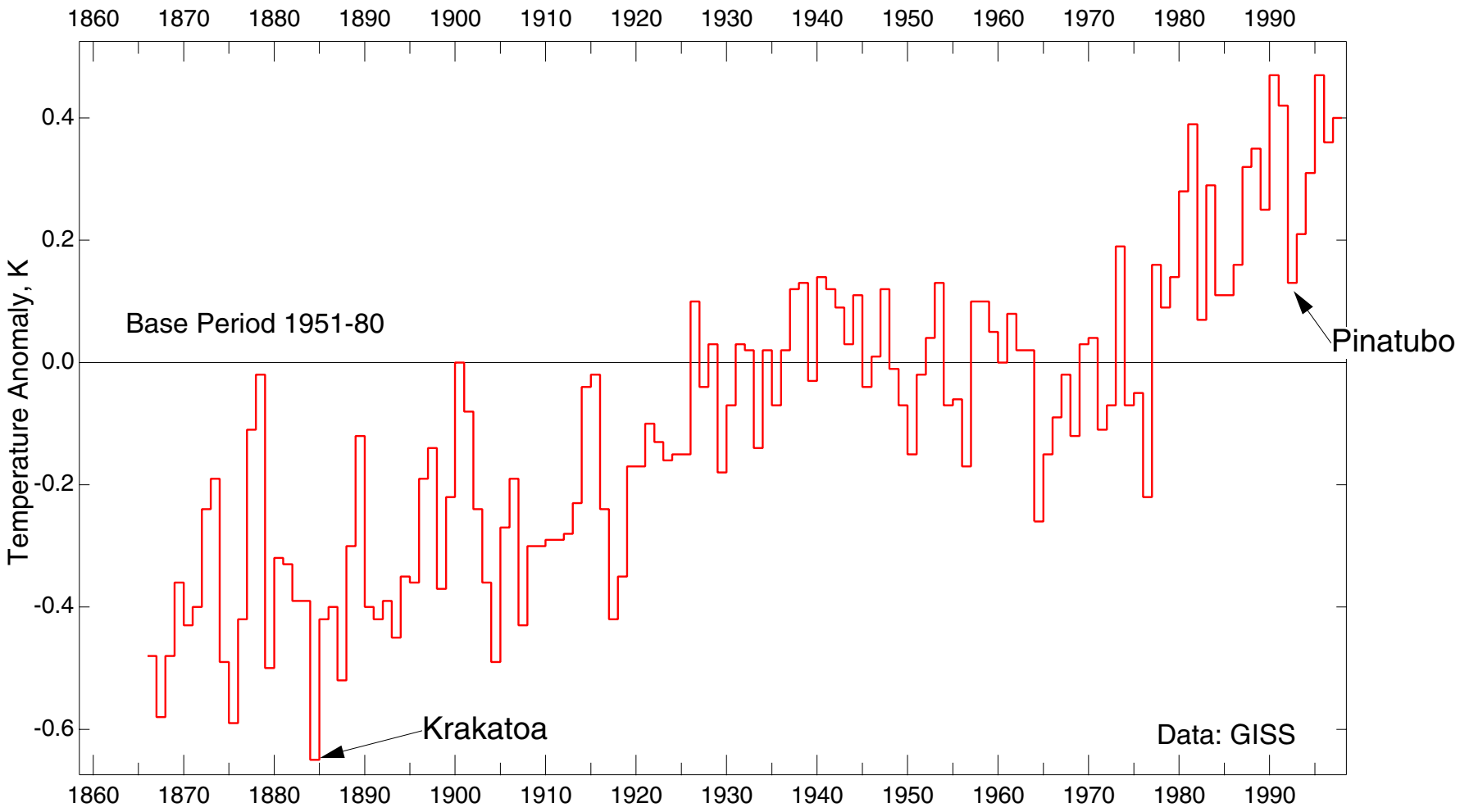
Climate sensitivity $\lambda = \Delta T / F$

- ***Climate models*** evaluated by performance on prior climate change, and/or

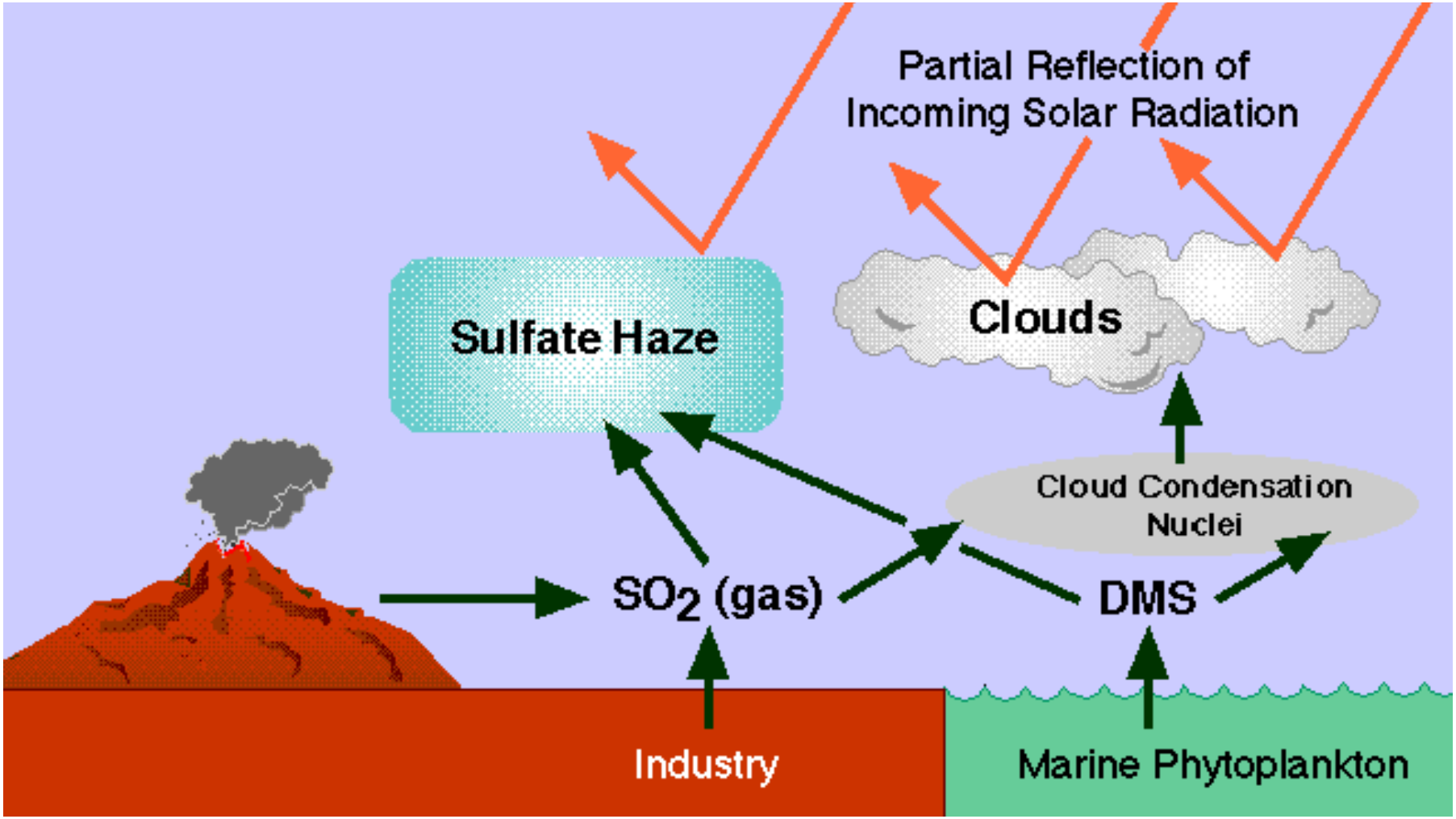
- ***Empirical determination*** from prior climate change.

- Either way, ΔT and F must be determined with sufficiently small uncertainty to yield an uncertainty in λ that is useful for informed decision making.

GLOBAL TEMPERATURE TREND OVER THE INDUSTRIAL PERIOD

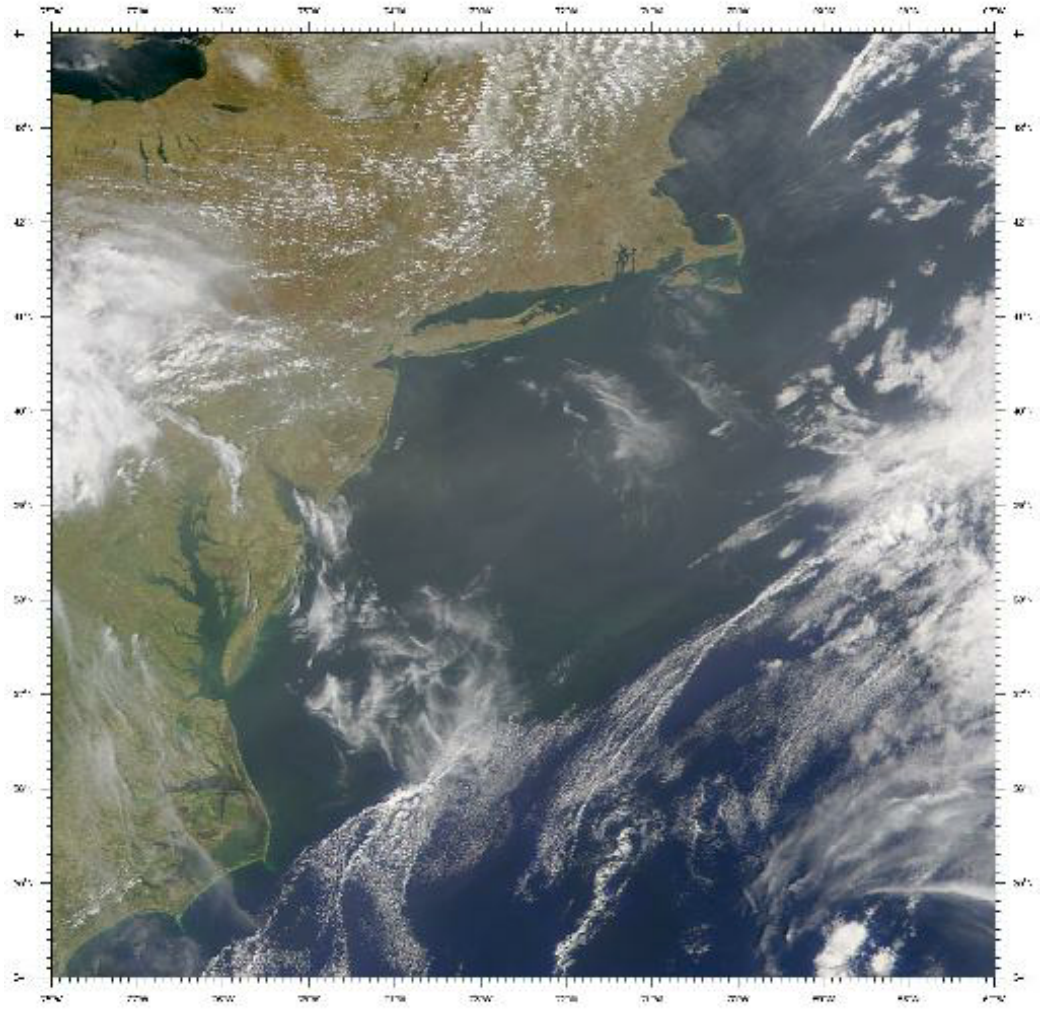


RADIATIVE FORCING OF CLIMATE CHANGE BY AEROSOLS



BIOMASS BURNING AND WIDESPREAD AEROSOL
Northeastern Oklahoma, 2000-12-01

AEROSOL: A suspension of particles in air



2001-04-22-17:28

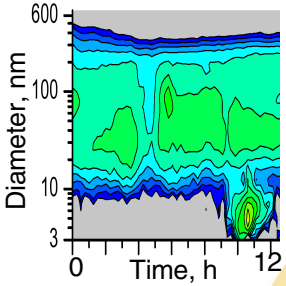
SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE

Atmospheric aerosols may result from primary emissions (dust, smoke) or from gas to particle conversion in the atmosphere (haze, smog).

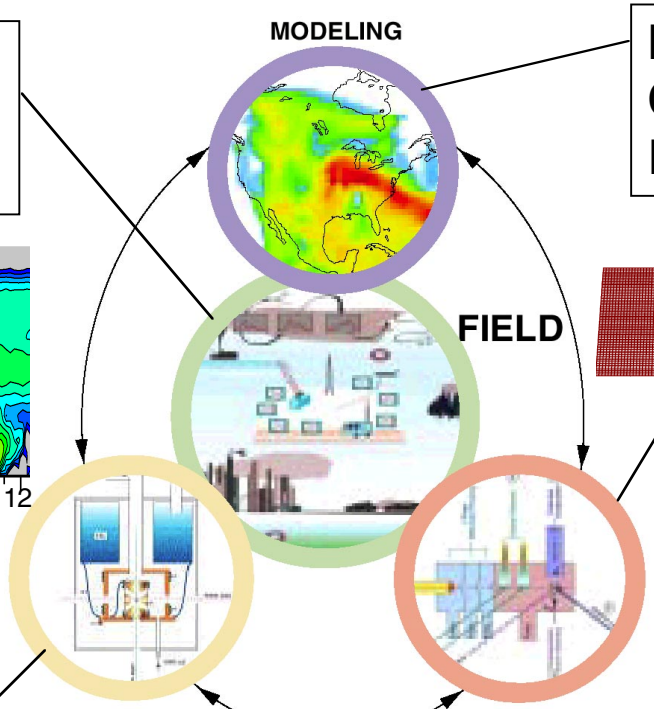
BNL AEROSOL RESEARCH OBJECTIVE AND CAPABILITIES

Provide knowledge needed to simulate and predict radiative forcing and climate effects of aerosols

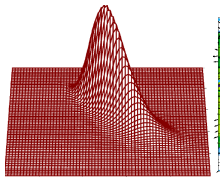
Aerosol lifecycle
Microphysical evolution
Indirect effects

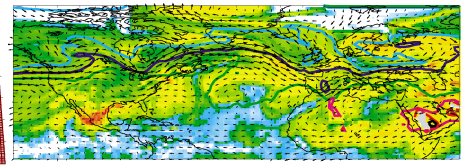


Aerosol formation
Aerosol transformations
Optical properties
Nucleating properties

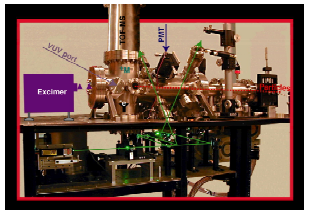


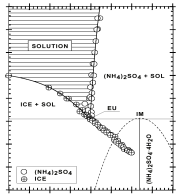
Microphysical models
Cloud-resolving models
Regional scale models

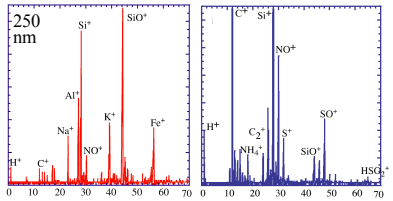




Size-resolved composition
Precursor gases
Absorption
Size distributions







SOME CONCLUDING OBSERVATIONS

- *The greenhouse effect is real and well understood.*
- *Atmospheric CO_2 is increasing and will continue to do so.*
- *Earth's climate may be expected to warm and otherwise change.*
- *Present understanding of Earth's climate is insufficient for informed policymaking.*
- *Aerosol forcing is comparable to greenhouse gas forcing but much more uncertain.*
- *Hence total forcing over the industrial period is highly uncertain.*
- *Hence the sensitivity of the climate system remains highly uncertain.*

(cont'd)

SOME CONCLUDING OBSERVATIONS (*cont'd*)

- *Climate sensitivity will remain uncertain unless and until aerosol uncertainty is substantially decreased.*
- *New and heightened efforts in DOE and at BNL are focusing on these aerosol influences.*
- *GHG concentrations and forcing are increasing. GHGs persist in the atmosphere for decades to centuries.*
- *Decisions must be made in an uncertain world. (Lack of controls on GHG emissions is also a decision).*